

Site Investigation Report for the Jackson Salt Water Spill Site Alexander, North Dakota

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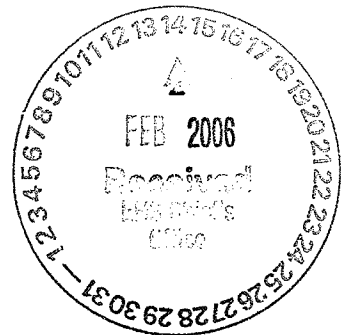
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February 2006



1.0 INTRODUCTION

Buys and Associates, Inc. (B&A) was retained by Zenergy, Inc. to conduct a limited investigation at the site of a salt water spill. The site is located in rural agricultural land near Alexander, North Dakota in Section 28, Township 150 North, Range 102 West. The location of the site is shown on Figure 1. This report also includes the results from water sampling conducted by others as well as the results from this investigation.

On January 4, 2006, a pipeline break was discovered on a produced water line. The spill involved a reported 22,000 barrels of produced water and occurred as the result of a seam failure in the 4-inch polyethylene pipeline. The produced water contained up to 180,000 parts per million (ppm) chloride, 70,000 ppm sodium, and 290 ppm ammonia. The released water flowed about 800 feet down a hillside into an unnamed ephemeral drainage, then 2,410 feet west along this upland drainage into Charbonneau Creek, a perennial tributary to the Yellowstone River. The Yellowstone River is located about 30 river miles away. The released water was ponded by two features along the unnamed drainage: a stock pond, and a muskrat pond (referred to as the "Beaver Pond"). Both of these features are formed by small earthen dams less than 10 feet high.

Cleanup activities were initiated by Zenergy immediately upon discovery of the spill. The pipeline was repaired on January 4, 2006 within 6 hours of the discovery, and the North Dakota Industrial Commission and available area landowners notified of the incident. Pumping of the water from the two ponds was initiated that day and has continued to the present. Pumping of affected water from Charbonneau Creek was also begun from two areas of the creek immediately downstream from the insertion point and at the north boundary of Section 33 T150N, R102W where a temporary dam was constructed to restrict the migration of the spill. The recovered water is transported by vacuum truck to the Zenergy Wolf #1 Salt Water Disposal Well for disposal. As of January 31, 2006, a total of 77,230 barrels of water has been removed (36,355 barrels from the stock pond, 23,965 barrels from the "beaver pond", and 16,910 barrels from Charbonneau Creek). Pumping of affected water from the creek is currently continuing at the rate of about 1,200 to 1,500 barrels per day. The stock pond and "beaver pond" were pumped until they were essentially dry. As water infiltrates these impoundments they are periodically emptied.

David K. Nicholson, Senior Geologist for B&A, inspected the site on January 12, 2006 to evaluate potential remediation options and plan for the limited site investigation. Samples were collected from two nearby domestic water wells at this time. The site investigation described in this report was conducted on January 19 and 20, 2006. The site investigation included the collection of soil samples from three points within the unnamed drainage and one point on the hillside below the spill, collection of four sediment samples downgradient of the spill site on Charbonneau Creek, collection of background samples for soils, sediment, and produced water, and a biological survey of Charbonneau Creek and the unnamed drainage. The methods and findings of the biological survey are provided in a separate report. Dissolved oxygen concentrations were also recorded at the existing water quality sampling locations at this time.

2.0 SITE INVESTIGATION PROCEDURES

Field activities were conducted by B&A during the period January 12, 19, and 20, 2006 and consisted of the following:

- Collection of seven soil samples from four locations along the unnamed drainage and analysis of these samples for Total Volatile Petroleum Hydrocarbons-Gasoline Range (TVPH) and Total Extractable Petroleum Hydrocarbons-Diesel Range (TEPH) by EPA Method 8015 Modified, Benzene, Toluene, Ethylbenzene, and Xylenes (BTEX) by EPA Method 8260B, metals by EPA Method 6010, mercury by EPA Method 7471, ammonia by EPA Method 4500, and chloride and sulfate by EPA Method E300.
- Collection of four sediment samples along Charbonneau Creek downgradient from the insertion point and analysis of these samples for metals, ammonia, chloride, and sulfate. The sediment sample closest to the insertion point was also analyzed for TVPH, TEPH, and BTEX.
- Collection of background soil and sediment samples from areas upgradient from the spill and analysis of these samples for metals, ammonia, chloride, and sulfate.
- Collection of one sample for the produced water and analysis of this sample for metals, ammonia, chloride, and sulfate.
- A biological survey of the unnamed drainage and Charbonneau Creek.

In addition to the investigation described above, water quality samples have been collected along the unnamed drainage and Charbonneau Creek by Baker Hughes and Astor-Chem Lab, Inc. The analytical results provided by Baker Hughes and Astro-Chem are also provided and discussed here. Additional water quality samples have been collected by the North Dakota Dept. of Health. However, results from those samples were not made available at the time of this report.

2.1 Surface Water Sampling

Following the discovery of the spill, Zenergy initially contracted with Baker Hughes to sample water from the affected areas of the unnamed drainage and Charbonneau Creek. Baker Hughes collected water samples from two locations on the unnamed drainage and one location on Charbonneau Creek and analyzed these samples for chloride on a daily basis between January 5 and January 9, 2006. Daily sampling and analysis was continued by Astro-Chem Lab, Inc. of Williston, North Dakota from January 10, 2006 to the present. Six additional monitoring sites further downstream on Charbonneau Creek were established on January 10, 2006 (Astro-Chem sites 1-6). Sites 2-6 are located on the Irwin and Cummings Ranches. Astro-Chem site #1 is located approximately 15 river miles downstream from the insertion point on Charbonneau Creek, at the concrete bridge crossing. Two additional sites were subsequently added further downstream on January 21, 2006 and January 27, 2006 respectively. Sulfate was added to the parameters that are monitored on January 13, 2006 and ammonia was added for some sites on an every other day basis on January 24, 2006. Astro-Chem also collected a background water samples for chloride and sulfate on January 20, 2006 and ammonia on January 25, 2006 from a location upgradient of the spill insertion point on Charbonneau Creek. The locations of the water

quality monitoring sites on the unnamed drainage and Charbonneau Creek are shown on Figure 2.

2.2 Soil Sampling

Seven soil samples were collected along the unnamed drainage and the hillside below the spill location. The locations of these samples are shown on Figure 3.

Samples were collected from two depths (0-6 inches and 6-18 inches) at three locations along the unnamed drainage. Samples ZJS-DS-01 and ZJS-DS-02 were collected from a small ponded area located about halfway down the unnamed drainage. The soils at this location were composed of dark brown to black clayey silt with some sand and gravel and abundant organic material. Samples ZJS-SPS-01 and ZJS-SPS-02 were collected from the stock pond along the unnamed drainage at the upgradient end of the pond, and samples ZJS-SPS-03 and ZJS-SPS-04 were collected from the stock pond at the downgradient end of the pond, adjacent to the earthen dam. At both locations, an organic-rich grayish-black silty clay layer is present above a layer of grayish-brown silty clay with some sand and gravel and less organic material. One sample (ZJS-HS-01) was collected on the hillside below the spill location from a depth of 0-4 inches. The soil at this location is composed of dark brown sandy silt with some organic material.

All soil samples were placed in clean, 4-ounce glass jars provided by the laboratory, placed on ice in a cooler, and shipped to Evergreen Analytical Laboratories, Inc. of Golden, Colorado for rush analysis of TVPH, TEPH, BTEX, metals, ammonia, chloride, and sulfate.

2.3 Sediment Sampling

Sediment samples were collected from four locations along Charbonneau Creek, as shown on Figure 2. The samples were collected from active sediment within the channel. Sample ZJS-CCSED-04 was collected just downstream from the unnamed drainage on Charbonneau Creek. Samples ZJS-CCSED-01 through ZJS-CCSED-03 were collected at roughly one-mile intervals further downgradient along Charbonneau Creek. These samples were analyzed for metals, ammonia, chloride, and sulfate. Sample ZJS-CCSED-04 was also analyzed for TVPH, TEPH, and BTEX.

All sediment samples were placed in clean, 4-ounce glass jars provided by the laboratory, placed on ice in a cooler, and shipped to Evergreen Analytical Laboratories, Inc. of Golden, Colorado for rush analysis.

2.4 Background Soil and Sediment Sampling

Background soil and sediment samples were collected as part of the investigation. The sample locations are shown on Figure 3. The background soil sample (ZJS-BKSOIL) was collected from a depth of 0-4 inches from a site located at the top of hill about ¼ mile east of the spill site. No oil and gas facilities are located near or upgradient from this site. The soil at this location consists of dark brown clayey silt.

The background sediment sample was collected from Charbonneau Creek about ½ mile upstream from the insertion point, as shown on Figure 2. No oil and gas facilities are located near or upgradient from this site.

These samples were placed in clean, 4-ounce glass jars provided by the laboratory, placed on ice in a cooler, and shipped to Evergreen Analytical Laboratories, Inc. of Golden, Colorado for rush analysis analyzed for metals, ammonia, chloride, and sulfate.

2.5 Produced Water Sampling

One sample of the produced water that was spilled was collected from a port at the Wolf #1 Well located in Section 28, T150N, R102W. This sample was shipped to Evergreen Analytical Laboratories, Inc. of Golden, Colorado for rush analysis of metals, chloride, sulfate, and ammonia.

2.6 Domestic Water Sampling

Two samples of domestic well water from the Wolf and Monson Ranches were collected. These samples were shipped to Evergreen Analytical Laboratories, Inc. of Golden, Colorado for rush analysis of chloride, sulfate, ammonia, sodium, and BTEX.

2.7 Dissolved Oxygen Measurements

Dissolved oxygen (DO) was measured at the water quality monitoring stations on Charbonneau Creek and in the "beaver pond" on January 20, 2006. The measurements were made in the stream using a YSI 550 DO meter. DO was also measured at the background water station at this time.

3.0 INVESTIGATION RESULTS

This section provides the analytical results for the samples collected during the investigation and compares these results to the background samples and the sample of the produced water.

3.1 Charbonneau Creek Water

Water in Charbonneau Creek has been monitored since the discovery of the spill for chloride, sulfate, and ammonia, as described previously. Chloride results are provided in Table 1, sulfate results are provided in Table 2, and ammonia results are provided in Table 3. The DO measurements recorded on January 20, 2006 are provided in Table 4. The monitoring locations along Charbonneau Creek are shown on Figure 2, and the background water quality monitoring station is shown on Figure 3. Laboratory data sheets for these analyses are provided in Appendix B.

Table 1 provides the chloride concentrations measured by Astro-Chem for the "beaver pond" (AC #8) and at eleven monitoring stations along Charbonneau Creek for the period January 5 to January 30, 2006. Figures 4-9 illustrate the chloride concentrations in the "beaver pond" and at key locations along Charbonneau Creek.

Table 1 Chloride in the "Beaver Pond" and Charbonneau Creek

Date	Monitoring Station ID												
	Dam	AC #8	AC #7	AC #6	AC #5	AC #4	AC#3	AC#2	AC#1B	AC#1A	AC#1	AC#9	AC#10
5-Jan	150000	85000	64000										
6-Jan	150000	64000	60000										
7-Jan	150000	56000	38000										
8-Jan	127000	21000	21000										
9-Jan	127000	21000	12470										
10-Jan	127000	21000	12470	3600	1670	180	20	20			14		
11-Jan	100000	12000	15000	7300	2200	480	180	62			10		
12-Jan		19600	10500	6500	2300	920	290	130			11		
13-Jan		22000	10000	8400	2300	1210	460	140			16		
14-Jan		22000	9100	4400	2100	1440	660	160	95	10	10		
15-Jan		18000	7800	4400	1900	1520	850	160	100	11	12		
16-Jan		21993	8397	3999	1999	1560	1200	190	146	18	14		
17-Jan		23993	8397	3999	1999	1580	1440	260	154	22	16		
18-Jan		22000	8800	4100	1900	1680	1480	260	146	36	16		
19-Jan		20000	9200	3600	1450	1770	1520	280	160	65	16		
20-Jan		15400	10000	3200	1360	1740	1580	400	180	84	22		
21-Jan		14400	10300	3400	1290	1540	1580	520	190	88	40	11	
22-Jan		12200	11000	2900	1100	1370	1680	730	180	90	40	12	
23-Jan		13400	9600	2600	1010	1290	1710	900	290	90	50	13	
24-Jan		12400	9300	2200	980	1000	1580	1140	380	90	60	18	
25-Jan		11800	8600	2200	850	710	1260	1340	630	120	90	34	
26-Jan		10400	8200	2000	900	1080	1000	1460	910	140	90	50	
27-Jan		12600	11200	4600	760	200	620	1520	1180	200	110	77	14
28-Jan		12300	8500	4200	770	220	140	890	1320	520	150	70	50
29-Jan		9000	15000	3400	780	260	230	320	760	1230	750	145	21
30-Jan		9200	13200	3300	760	380	250	240	400	1140	1100	440	40

All results in mg/L

Figure 4 shows chloride concentrations in the unnamed drainage that received the spill, measured in the "beaver pond". The chloride concentration was initially measured as

85,000 mg/L on January 5, 2006. Active remediation (pumping of water from the "beaver pond") rapidly reduced the concentration to about 20,000 mg/L by January 8, 2006. Chloride rebounded to about 22,000 mg/L on January 17, 2006 and has gradually dropped to about 9,000 mg/L at this location since that time.

Figure 5 shows chloride concentrations in Charbonneau Creek at the point where the creek has been dammed and pumped near the north boundary of Section 33, T150N, R102W. Chloride concentrations at this location were initially as high as 64,000 mg/L on January 5, 2006, immediately following discovery of the spill. The concentration of chloride dropped to about 10,000 mg/L by January 13, 2006 and has remained close to this concentration since that time. Figure 6 shows the chloride concentrations at a location east of the Irwin Ranch, about 3.5 river miles downstream from the spill insertion point. Chloride was as high as 8,400 mg/L at this location on January 13, 2006, dropped to 2,000 mg/L on January 26, 2006, and has recently increased to about 3,300 mg/L. Figure 7 shows chloride at the south boundary of the Cummings Ranch, about 8 river miles downstream of the spill site. Chloride was close to the background concentration of about 12 mg/L at this location, gradually increased to a maximum of 1,710 mg/L on January 25, 2006, and has since declined to about 250 mg/L. Figure 8 shows chloride at the concrete bridge crossing, about 15 river miles downstream. Background concentrations of chloride were seen at this location until about January 20, 2006. The concentration of chloride at this location gradually increased to about 150 mg/L between January 21 and January 28, 2006, then increased to 1,100 mg/L by January 30, 2006. Two more monitoring points were established in response to the movement of chloride past the concrete bridge. Chloride was detected at concentrations of 440 mg/L and 40 mg/L at these two stations on January 30, 2006, indicating that chloride is still moving downstream in Charbonneau Creek. Figure 9 shows the chloride concentration at the furthest downstream site, located south of the Teldje Ranch.

Figure 10 shows chloride in Charbonneau Creek from January 10 to January 30, 2006 at five downstream locations (Astro-Chem monitoring stations 1-5). These stations are located across the Irwin and Cummings ranches. Figure 10 shows the movement of chloride-impacted water down the stream during this time. This figure also illustrates the effect of dilution on the chloride concentrations in Charbonneau Creek. Peak chloride concentrations at each successively downstream station are lower than for the station immediately upstream. As shown by this figure, peak chloride concentrations were about 2,300 mg/L at station AC #5, 1,750 mg/L at station AC #4, 1,700 mg/L at station AC #3, and 1,500 mg/L at station AC #2. The main pulse of chloride-impacted water arrived at station AC #1 on January 28, 2006.

Table 2 provides the sulfate concentrations measured by Astro-Chem for the "beaver pond" (AC #8) and at eleven monitoring stations along Charbonneau Creek for the period January 5 to January 30, 2006. Figures 11-15 illustrate the sulfate concentrations in the "beaver pond" and at key locations along Charbonneau Creek.

Table 2 Sulfate in Charbonneau Creek

Date	Monitoring Station ID											
	AC #8	AC #7	AC #6	AC #5	AC #4	AC #3	AC #2	AC#1B	AC#1b	AC #1	AC #9	AC#10
13-Jan	470	1790	1100	997	790	631	603			603		
14-Jan	631	1770	1140	964	745	687	645	659	631	617		
15-Jan	576	1920	1140	899	867	716	687	687	775	716		
16-Jan	836	1766	1031	867	899	687	549	631	964	836		
17-Jan	997	1816	1100	997	931	931	775	716	1136	867		
18-Jan	1030	2090	1490	899	836	964	659	659	964	931		
19-Jan	867	2088	1209	899	931	805	745	745	964	931		
20-Jan	931	2271	1247	805	931	775	687	631	867	964		
21-Jan	1031	2336	1405	899	964	745	603	687	836	964	964	
22-Jan	1209	2271	1285	931	867	836	805	687	775	931	1065	
23-Jan	1285	2697	1405	1100	1031	964	836	836	899	1405	1285	
24-Jan	1031	2336	1136	931	867	775	931	931	964	867	1031	
25-Jan	1209	2336	1405	1100	867	964	1031	867	899	775	1100	
26-Jan	1136	2088	1136	899	805	1065	1031	997	867	836	1065	
27-Jan	997	1717	1100	964	451	603	1136	931	745	805	997	1578
28-Jan	1065	1975	1100	899	415	371	805	931	745	805	964	1325
29-Jan	1065	1578	1065	964	451	399	298	775	745	716	836	1172
30-Jan	1209	1578	1065	964	495	432	451	576	931	805	836	1136

All results in mg/L

Figure 11 shows sulfate concentrations in the unnamed drainage from January 13 to January 30, 2006. Sulfate initially increased at the beaver pond station from about 450 mg/L to about 1,300 mg/L between January 13 and January 23, 2006. Sulfate has ranged between 1,000 mg/L and 1,200 mg/L since then. However, sulfate was measured at 2,031 mg/L at the background station located upstream from the Monson Ranch on January 20, 2006.

Figures 12, 13, 14, and 15 show sulfate at four stations along Charbonneau Creek. Sulfate concentrations show no obvious pattern at these locations and is highly variable from day to day. Given that most of the sulfate measurements are lower than the background sample, the wide variability in concentrations, and the lack of a pattern that mimics the chloride concentrations seen in Charbonneau Creek, it appears that these sulfate concentrations are representative of natural conditions in the creek.

Ammonia has been measured at three locations on Charbonneau Creek on three occasions beginning on January 24, 2006. Table 3 provides these results. Ammonia ranges from 0.27 mg/L to 6.05 mg/L for these analyses. Ammonia was reported as 0.39 mg/L for the background sample collected upstream of the Monson Ranch on January 26, 2006. Ammonia is also present in the produced water at a concentration of 290 mg/L and was detected in the soil samples collected from the unnamed drainage. Therefore, it appears that the elevated ammonia detected in Charbonneau Creek is associated with the spill.

Table 3 Ammonia in Charbonneau Creek

Sample Point	Date		
	24-Jan	26-Jan	30-Jan
Crossing E. Of Irwin Ranch (AC #6)	6.05	0.34	10
Concrete Bridge (AC #1)	0.37	0.34	0.37
S of Tjelde Ranch (AC #9)	0.32	5.35	0.27

All results in mg/L

Table 4 provides the DO measurements recorded on January 20, 2006. DO ranged from 4.71 mg/L to 5.40 mg/L along Charbonneau Creek, and was 4.75 mg/L at the background station. These values indicate that the creek has not been impacted by petroleum constituents. The high DO of 11.02 mg/L recorded in the "beaver pond" reflects an absence of biological activity in this pond.

Table 4 Dissolved Oxygen Measurements

Site ID	DO
Beaver Pond (AC #8)	11.02
CB Creek (AC #7)	5.26
Irwin Ranch (AC #6)	5.18
East of Irwin Ranch (AC #5)	4.96
By Pig Launcher (AC #4)	4.82
South Boundary (AC #3)	5.01
By Cattle Guard (AC #2)	4.71
AC #1B	4.78
AC #1A	5.40
Concrete Bridge (AC #1)	5.29
Upgradient (Background)	4.75

3.2 Hillside and Unnamed Drainage Soils

Analytical results for the soil samples collected from the hillside below the spill site and the unnamed drainage are provided in Table 5 and the sample locations are shown on Figure 3. Laboratory data sheets for these analyses are provided in Appendix C.

Table 5 Soil Analytical Results

		Sample ID							
	Depth	0-4"	0-4"	0-6"	6-18"	0-6"	6-18"	0-6"	6-18"
Parameter	Units	ZJS-BKSOIL	ZJS-HS-01	ZJS-DS-01	ZJS-DS-02	ZJS-SPS-01	ZJS-SPS-02	ZJS-SPS-03	ZJS-SPS-04
Metals									
Antimony	mg/kg	ND UJ	ND UJ	ND UJ	ND UJ	ND UJ	ND UJ	ND UJ	ND UJ
Arsenic	mg/kg	ND	6.1	ND	ND	ND	4.6	ND	ND
Barium	mg/kg	100	38	120	130	110	66	150	160
Beryllium	mg/kg	0.27	0.30	0.25	0.32	0.33	0.21	0.47	0.49
Cadmium	mg/kg	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	mg/kg	4.7	5.9	ND	ND	4.2	4.5	6.8	7.5
Copper	mg/kg	7.9	7.7	8.4	11	10	6.1	16	14
Iron	mg/kg	8,700 J	13,000 J	8,400 J	9,700 J	8,800 J	7,600 J	9,700 J	11,000 J
Lead	mg/kg	ND	ND	ND	ND	ND	ND	ND	ND
Manganese	mg/kg	260	230	190	240	110	130	110	91
Nickel	mg/kg	8.8	11	10	12	10	8.1	12	12
Selenium	mg/kg	ND	ND	ND	ND	ND	ND	ND	ND
Silver	mg/kg	ND	ND	ND	ND	ND	ND	ND	ND
Sodium	mg/kg	370 J	6,900 J	24,000 J	19,000 J	2,000 J	15,000 J	27,000 J	25,000 J
Thallium	mg/kg	ND	ND	ND	ND	ND	ND	ND	ND
Zinc	mg/kg	27	24	28	34	32	19	45	43
Mercury	mg/kg	0.021	0.035	0.037	0.034	0.028	0.023	0.049	0.041
Anions									
Chloride	mg/kg	758	10,100	63,500	15,900	53,200	25,600	58,300	34,900
Sulfate	mg/kg	17	ND	627	932	343	172	248	111
Ammonia	mg/kg	ND	12.4	39.7	18.9	30.6	17.5	41.3	31.8
Petroleum Constituents									
TVPH	mg/kg	NA	14 J	2.1 J	1.1 J	1.3 J	1.1 J	4.8 J	1.9 J
TEPH	mg/kg	NA	460	ND	ND	ND	ND	ND	ND
Benzene	ug/kg	NA	170 J	430 J	60 J	ND UJ	ND UJ	620 J	300 J
Toluene	ug/kg	NA	790	210	ND	ND	ND	890	230
Ethylbenzene	ug/kg	NA	440	ND	ND	ND	ND	140	ND
Total xylenes	ug/kg	NA	1430	ND	ND	ND	ND	360	32

ND = Not Detected

NA = Not Analyzed

UJ = Not detected; detection limit is estimated

J = Estimated concentration

Barium, beryllium, chromium, copper, iron, manganese, nickel, sodium, zinc, and mercury were detected in the background soil sample. All of these metals were also detected in one or more of the site soil samples. Iron is naturally present at very high concentrations (8,400 mg/kg to 13,000 mg/kg) in these soils. All concentrations of these metals in the site soils are within roughly 2 times the background concentration, except for sodium. Sodium is present in the hillside soils at a concentration of 6,900 mg/kg

(about 18 times the background concentration of 370 mg/kg) and in the soils in the unnamed drainage at concentrations ranging from 2,000 mg/kg to 27,000 mg/kg (about 5 to 73 times the background concentration). Sodium was also reported at a concentration of 47,000 mg/L in the produced water (see Table 7 below). Arsenic was also detected in two site soil samples at trace concentrations of 6.1 mg/kg and 4.6 mg/kg, but was not detected in the background sample.

The consistent nature of the sample results and the presence of similar concentrations of metals for the background sample and the site samples, except for sodium, demonstrate that these concentrations are representative of natural (background) levels of metals in soils of the region, which are derived from the underlying shale bedrock. For arsenic, the average concentration of arsenic in soils has been reported to range from 5.2 to 7.5 mg/kg (Shacklette and Boerngen 1984 and references cited within). The concentration of arsenic in shales is generally elevated above these averages. Rose (2003) reported that the average concentration of arsenic in common shales and black shales is 12 mg/kg and 29 mg/kg, respectively.

Chloride was reported as 758 mg/kg in the background soil sample. Chloride concentrations in the soil samples from the hillside and unnamed drainage range from 10,100 mg/kg to 63,500 mg/kg. These concentrations are about 13 to 84 times the background concentration. Chloride is present at a concentration of 70,300 mg/L in the produced water (see Table 7 below). Chloride is consistently higher in the three samples collected from 0-6 inches depth than the paired samples collected from 6-18 inches depth.

Sulfate was reported at a concentration of 17 mg/kg in the background soil sample and 676 mg/L in the produced water. The sample of soil from the hillside had non-detect sulfate, and the samples from the unnamed drainage have sulfate concentrations ranging from 111 mg/kg to 932 mg/kg. No consistent pattern of sulfate with depth is noted for the three paired sample sets collected from the unnamed drainage. Sulfate is higher in the sample collected from 6-18 inches for the location closest to the spill site, and lower in the deeper sample for the other two sample pairs collected from the stock pond. In addition, sulfate was reported as 2 mg/L and 575 mg/L for the samples collected from two domestic water wells in the area (see Table 8 below). Therefore, it appears that the elevated sulfate seen in the soil samples from the unnamed drainage reflects natural variation of sulfate in the area.

Ammonia was not detected in the background soil sample but is present at concentrations ranging from 12.4 mg/kg to 41.3 mg/kg in the soils from the hillside and the unnamed drainage. Ammonia is present at both depths sampled and is consistently higher in the upper sample. Ammonia is also present in the produced water at a concentration of 290 mg/L.

Total Extractable Petroleum Hydrocarbons (TEPH – diesel range) was reported at a concentration of 460 mg/kg in the hillside soils and is non-detect in the soils in the unnamed drainage. Total Volatile Petroleum Hydrocarbons (TVPH – gasoline range) was reported at a concentration of 14 mg/kg in the hillside soils and ranges from 1.1 mg/kg to 4.8 mg/kg in the soils in the unnamed drainage. Trace concentrations of benzene, toluene, ethylbenzene, and xylenes were also detected in the hillside soils and the soils from the stock pond.

Based on the results provided above, the hillside soils and soils within the unnamed drainage, including the stock pond, have been impacted by sodium, chloride, ammonia, and petroleum constituents from the spill. The depth of the impacted soil beneath the drainage is not known, but is at least 18 inches. Soil samples were not collected from the "beaver pond" during this investigation because the pond was flooded and mostly frozen. However, it is assumed that the soils beneath the beaver pond have also been impacted by the spill.

3.3 Charbonneau Creek Sediments

Five sediment samples were collected from Charbonneau Creek. Four samples were collected downstream of the spill site and one sample was collected upgradient of the site to serve as the background sample. Analytical results for the sediment samples are provided in Table 6. Sample locations on Charbonneau Creek are shown on Figure 2 and the background sampling location is shown on Figure 3. Laboratory data sheets for these analyses are provided in Appendix C.

Antimony, arsenic, barium, beryllium, chromium, copper, iron, manganese, nickel, sodium, and zinc were detected in the background sediment sample. All of these metals were also detected in one or more of the sediment samples from Charbonneau Creek. Iron is naturally present at very high concentrations (4,600 mg/kg to 17,000 mg/kg) in these sediments. All concentrations of these metals in the sediments are less than the background concentration, except for chromium and sodium. Chromium is present in one sample at a concentration slightly higher than background, and was not detected in the other three samples. Sodium is present in the sediments at concentrations ranging from 470 mg/kg (about 1.3 times the background concentration of 350 mg/kg) to 1,500 mg/kg (about 4.3 times the background concentration). Sodium is present at a concentration of 47,000 mg/L in the produced water (see Table 7 below). Mercury was detected at a low concentration of 0.019 mg/kg in one sediment sample.

Chloride was reported as 15.2 mg/kg in the background sediment sample. Chloride concentrations in the sediment samples from Charbonneau Creek range from 42.5 mg/kg to 2,440 mg/kg. These concentrations are about 2.8 to 160 times the background concentration. Chloride is present at a concentration of 70,300 mg/L in the produced water (see Table 7 below).

Sulfate was reported at a concentration of 253 mg/kg in the background sediment sample and 676 mg/L in the produced water. Sulfate concentrations for the four sediment samples from Charbonneau Creek range from 268 mg/kg to 1,080 mg/kg. As discussed for soils, no consistent pattern of sulfate with distance downstream is noted. In addition, sulfate was reported as 2 mg/L and 575 mg/L for the samples collected from two domestic water wells in the area (see Table 8 below). Therefore, it appears that the elevated sulfate seen in the sediment samples from Charbonneau Creek reflects natural variation of sulfate in the area.

Table 6 Sediment Analytical Results

		Sample ID				
Parameter	Units	ZJS-BKSED	ZJS-CCSED-01	ZJS-CCSED-02	ZJS-CCSED-03	ZJS-CCSED-04
Metals						
Antimony	mg/kg	1.6 J	ND UJ	ND UJ	ND UJ	ND UJ
Arsenic	mg/kg	20	ND	ND	ND	7.3
Barium	mg/kg	130	55	54	43	94
Beryllium	mg/kg	0.19	0.089	0.089	0.052	0.16
Cadmium	mg/kg	ND	ND	ND	ND	ND
Chromium	mg/kg	2.8	ND	ND	ND	3.0
Copper	mg/kg	7.1	4.6	3.2	1.7	3.6
Iron	mg/kg	17,000 J	5,600 J	4,600 J	4,400 J	14,000 J
Lead	mg/kg	ND	ND	ND	ND	ND
Manganese	mg/kg	700	130	130	150	400
Nickel	mg/kg	11	6.2	5.5	3.0	7.9
Selenium	mg/kg	ND	ND	ND	ND	ND
Silver	mg/kg	ND	ND	ND	ND	ND
Sodium	mg/kg	350 J	1,500 J	940 J	520 J	470 J
Thallium	mg/kg	ND	ND	ND	ND	ND
Zinc	mg/kg	15	13	10	6.2	12
Mercury	mg/kg	ND	0.019	ND	ND	ND
Anions						
Chloride	mg/kg	15.2	2230	2440	42.5	132
Sulfate	mg/kg	253	766	1080	268	418
Ammonia	mg/kg	ND	ND	ND	ND	ND
Petroleum Constituents						
TVPH	mg/kg	NA	NA	NA	NA	ND UJ
TEPH	mg/kg	NA	NA	NA	NA	ND
Benzene	ug/kg	NA	NA	NA	NA	ND UJ
Toluene	ug/kg	NA	NA	NA	NA	ND
Ethylbenzene	ug/kg	NA	NA	NA	NA	ND
Total xylenes	ug/kg	NA	NA	NA	NA	ND

ND = Not Detected

NA = Not Analyzed

UJ = Not detected; detection limit is estimated

J = Estimated concentration

Ammonia was not detected in any sediment samples. TEPH, TVPH, and BTEX were analyzed for the sediment sample located just downstream from the insertion point and all results were non-detect.

Based on the results provided above, the sediments in Charbonneau Creek have been impacted by sodium and chloride from the spill. The concentrations of both parameters in the sediments decrease rapidly downstream.

Table 7 Produced Water Analytical Results

Parameter	Units	ZJS-BRINE
Metals		
Antimony	mg/L	ND
Arsenic	mg/L	ND
Barium	mg/L	0.68
Beryllium	mg/L	ND
Cadmium	mg/L	ND
Chromium	mg/L	ND
Copper	mg/L	ND
Iron	mg/L	23
Lead	mg/L	ND
Manganese	mg/L	0.61
Nickel	mg/L	ND
Selenium	mg/L	ND
Silver	mg/L	ND
Sodium	mg/L	47,000
Thallium	mg/L	ND
Zinc	mg/L	ND
Mercury	mg/L	ND
Anions		
Chloride	mg/L	70,300
Sulfate	mg/L	676
Ammonia	mg/L	290

ND = Not Detected

Table 8 Domestic Water Analytical Results

Parameter	Units	WOLF	MONSON
Sodium	mg/L	540 J	420 J
Total Dissolved Solids	mg/L	1,440	1,610
Chloride	mg/L	9.5	3.4
Sulfate	mg/L	2.0	575
Ammonia	mg/L	ND	290
Benzene	ug/kg	ND	ND
Toluene	ug/kg	ND	ND
Ethylbenzene	ug/kg	ND	ND
Total xylenes	ug/kg	ND	ND

ND = Not Detected

J = Estimated concentration

4.0 SUMMARY AND CONCLUSIONS

4.1 Summary of Impacts

4.1.1 Charbonneau Creek Water

Water sampling results show that Charbonneau Creek has been impacted by sodium, chloride, and ammonia as a result of the spill of produced water. Chloride concentrations in Charbonneau Creek immediately downstream of the spill insertion point were initially as high as 64,000 mg/L on January 5, 2006, immediately following discovery of the spill. The concentration of chloride at this location dropped to about 10,000 mg/L by January 13, 2006 due to active remediation of the creek and has remained close to this concentration since that time. Although the bulk of the available impacted water has been pumped from this area, chloride concentrations remain high due to the lack of dilution.

Elevated chloride concentrations are present along Charbonneau Creek to the concrete bridge crossing, about 15 river miles downstream. Background concentrations of chloride were seen at this location until about January 20, 2006. The concentration of chloride at this location gradually increased to about 150 mg/L between January 21 and January 28, 2006, then increased to 1,100 mg/L by January 30, 2006. Two more monitoring points were established in response to the movement of chloride past the concrete bridge. Chloride was detected at concentrations of 440 mg/L and 40 mg/L at these two stations on January 30, 2006, indicating that chloride is still moving downstream in Charbonneau Creek.

Sulfate concentrations along Charbonneau Creek show no obvious pattern and are highly variable from day to day. Given that most of the sulfate measurements are lower than the background sample, the wide variability in concentrations, and the lack of a pattern that mimics the chloride concentrations seen in Charbonneau Creek, it appears that these sulfate concentrations are representative of natural conditions in the creek.

Ammonia ranges from 0.27 mg/L to 6.05 mg/L for samples collected from Charbonneau Creek and was reported as 0.39 mg/L for the background sample. Therefore, it appears that the elevated ammonia detected in Charbonneau Creek is associated with the spill.

DO was measured on January 20, 2006 and ranged from 4.71 mg/L to 5.40 mg/L along Charbonneau Creek, and was 4.75 mg/L at the background station. These values indicate that the creek has not been impacted by increased biological or chemical oxygen demand as a result of the incident.

4.1.2 Soils

The hillside soils immediately below the spill point and the soils within the unnamed drainage, including the stock pond, have been impacted by sodium, chloride, ammonia, and petroleum constituents from the spill. The depth of the impacted soil beneath the drainage is not known, but is at least 18 inches. Soil samples were not collected from the "beaver pond" during this investigation because the pond was flooded and mostly frozen. However, it is assumed that the soils beneath the beaver pond have also been impacted by the spill.

Sodium is present in the hillside soils below the spill point at a concentration of 6,900 mg/kg (about 18 times the background concentration of 370 mg/kg) and in the soils in the unnamed drainage at concentrations ranging from 2,000 mg/kg to 27,000 mg/kg (about 5 to 73 times the background concentration). Chloride concentrations in the soil samples from the hillside and unnamed drainage range from 10,100 mg/kg to 63,500 mg/kg. These concentrations are about 13 to 84 times the background concentration of 758 mg/kg. Chloride is higher in the three samples collected from 0-6 inches depth than the paired samples collected from 6-18 inches depth.

Sulfate concentrations in soils were highly variable, ranging from 111 mg/kg to 932 mg/kg in the unnamed drainage soils, non-detect in the hillside soils, and 17 mg/kg in the background soil sample. It is considered that the elevated sulfate seen in the soil samples from the unnamed drainage reflects the natural variation of sulfate in the area.

Ammonia was not detected in the background soil sample but is present at concentrations ranging from 12.4 mg/kg to 41.3 mg/kg in the soils from the hillside and the unnamed drainage. Ammonia is present at both depths sampled and is consistently higher in the upper sample. Therefore, it appears that the elevated ammonia observed in these samples is related to the spill of produced water.

The metals analyses of the produced water and background soil and sediments demonstrate that, with the exception of sodium, the metals concentrations observed are representative of natural (background) levels of metals in soils of the region, which are derived from the underlying shale bedrock. Iron is naturally present at very high concentrations (8,400 mg/kg to 13,000 mg/kg) in these soils.

TEPH – diesel range was reported at a concentration of 460 mg/kg in the hillside soils and is non-detect in the soils in the unnamed drainage. TVPH – gasoline range was reported at a concentration of 14 mg/kg in the hillside soils and ranges from 1.1 mg/kg to 4.8 mg/kg in the soils in the unnamed drainage. Trace concentrations of benzene, toluene, ethylbenzene, and xylenes were also detected in the hillside soils and the soils from the stock pond.

4.1.3 Charbonneau Creek Sediments

Sediments in Charbonneau Creek have been impacted by sodium and chloride from the spill. The concentrations of both parameters in the sediments decrease rapidly downstream. Sodium is present in the sediments along the first three miles of Charbonneau Creek at concentrations ranging from 470 mg/kg (about 1.3 times the background concentration of 350 mg/kg) to 1,500 mg/kg (about 4.3 times the background concentration). Chloride concentrations in the sediment samples from Charbonneau Creek range from 42.5 mg/kg to 2,440 mg/kg. These concentrations are about 2.8 to 160 times the background concentration of 15.2 mg/kg.

Sulfate concentrations for the four sediment samples from Charbonneau Creek range from 268 mg/kg to 1,080 mg/kg. As for the soils and water, it appears that the elevated sulfate seen in the sediment samples from Charbonneau Creek reflects natural variation of sulfate in the area.

Ammonia was not detected in any sediment samples. TEPH, TVPH, and BTEX were analyzed for the sediment sample located just downstream from the insertion point and

all results were non-detect.

All concentrations of metals in the sediments are less than the background concentration, except for chromium and sodium. Chromium is present in one sample at a concentration slightly higher than background, and was not detected in the other three samples.

4.2 Conclusions

Based on the results of this investigation and water sampling performed by Astro-Chem, Charbonneau Creek and the soils in the unnamed drainage have been impacted by chloride, sodium, and ammonia. Soils in the unnamed drainage have been also been impacted by petroleum constituents from the spill. The spill does not appear to be the source of the high sulfate observed. Monitoring of sulfate concentrations is not necessary and should be discontinued.


The current remediation effort should be continued, and additional remediation techniques for restoration of the soils in the unnamed drainage should be considered.

Please call either of the undersigned if you have any questions regarding this report.

Sincerely,
Buys and Associates, Inc.



Doug Henderer
Project Manager



David K. Nicholson, P.G.
Senior Geologist

**Phase II Site Investigation Report and Revised
Remediation and Monitoring Plan
for the
Jackson Salt Water Spill Site
Alexander, North Dakota**

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1.0 INTRODUCTION

Buys and Associates, Inc. (B&A) was retained by Zenergy, Inc. to conduct remediation at the site of a salt water spill. The site is located in rural agricultural land near Alexander, North Dakota in Section 28, Township 150 North, Range 102 West. Previous reports presented the results from a limited site investigation conducted by B&A and water sampling conducted by others, the results of biological surveys conducted by B&A along Charbonneau Creek, and a preliminary remediation and monitoring plan for the site. This report provides the results of the Phase II Site Investigation conducted by B&A during the period May 22-25, 2006, and presents a revised Remediation and Monitoring Plan for the continued restoration of the site and Charbonneau Creek.

The results of the previous investigations at the site show that Charbonneau Creek has been impacted by sodium, chloride, and ammonia downstream of the spill site as a result of the spill of produced water. The concentration of chloride in Charbonneau Creek water was initially as high as 64,000 mg/L on January 5, 2006, immediately following discovery of the spill. The concentration of chloride at this location dropped to about 10,000 mg/L by January 13, 2006 due to active remediation of the creek and remained close to this concentration until February 2, 2006, when concentrations began falling again. Concentrations of chloride decreased throughout the spring flush period, when large quantities of water were flowing in the creek, but now have begun to rise again as flows within the creek decrease. The chloride monitoring has revealed that a source of salt contamination within the unnamed upland drainage continues to enter and impact the water quality in Charbonneau Creek.

In addition, previous sampling results also showed that the hillside soils immediately below the spill point and the soils within the upland drainage, including the stock pond and "beaver pond", are impacted by sodium, chloride, and ammonia from the spill. Sediments in Charbonneau Creek have also been impacted by sodium and chloride from the spill. Previous sampling showed that the concentrations of both parameters in the sediments decrease rapidly downstream. In addition to these parameters, it is also possible that the concentrations of some metals may be elevated in the soils and sediments as a result of the spill.

The Phase II Site Investigation was initiated to:

1. Further delineate the extent of salt contamination in soils on the hillside, in the upland drainage, and in the "beaver pond";
2. Evaluate the reasons why the stock pond has refilled with relatively clean water at the same time that salt-contaminated water continues to enter Charbonneau Creek, including the possible presence of a subsurface layer of enhanced permeability that may act to channel salt-contaminated groundwater below the stock pond, or stratification of the stock pond water;
3. Evaluate the persistence of salt contamination and metals concentrations in sediments of Charbonneau Creek;
4. Evaluate the natural concentrations of metals and anions in soils of the area; and
5. Obtain physical and chemical data necessary to evaluate remedial alternatives, including the upland drainage channel geometry, the depth to competent bedrock or clay layers, the nature of the shallow groundwater system, and parameters required to evaluate remediation of the soils using chemical amendments.

2.0 PHASE II SITE INVESTIGATION

The Phase II Site Investigation was performed during the period May 22-25, 2006 and consisted of the following activities:

- Drilling of 10 soil borings using a hollow-stem auger drill rig.
- Sampling of background soil borings at two depths (0-1 ft and 2-4 ft) at three locations and analysis of these samples for Target Analyte List (TAL) metals, chloride, pH, Specific Conductance (SC), Sodium-Adsorption Ratio (SAR), cation-exchange capacity (CEC), and exchangeable sodium percentage (ESP).
- Sampling of one soil boring located in the upland drainage above the stock pond at three depths and analysis of these samples for chloride, pH, SC, SAR, CEC, and ESP.
- Sampling of one boring located on the hillside at three depths and analysis of these samples for chloride, pH, SC, SAR, CEC, and ESP.
- Installation of two borings located adjacent to the "beaver pond" and one boring at the top of the upland drainage to evaluate the presence of saturated alluvium and the depth to competent bedrock or clay layers.
- Drilling of one boring on the stock pond dam to evaluate the possible presence of a subsurface permeable layer below the stock pond and completion of this boring as a monitoring well.
- Drilling of one boring downstream of the stock pond to evaluate the possible presence of a subsurface permeable layer at this location and completion of this boring as a monitoring well.
- Collection of groundwater samples from both monitoring wells and analysis of these samples for TAL metals, chloride, sulfate, and ammonia.
- Collection of surface water samples from a background location upgradient of the Monson ranch, from the stock pond, and from Charbonneau Creek immediately downstream from the spill insertion point, and analysis of these samples for TAL metals, chloride, sulfate, and ammonia.
- Excavation of two trenches within the "beaver pond" using a trackhoe, sampling of these trenches at two depths (0-1 ft and 4-5 ft), and analysis of these samples for chloride, pH, SC, SAR, CEC, and ESP.
- Excavation of one trench across the upland drainage to investigate the channel morphology.
- Collection of one sediment sample from Charbonneau Creek near the insertion point and analysis of this sample for TAL metals, chloride, and ammonia.
- Collection of five additional sediment samples from further downgradient along Charbonneau Creek and analysis of these samples for chloride.

2.1 Phase II Site Investigation Results

The results from the Phase II Site Investigation described above and a summary of the current understanding of the impacts from the spill to Charbonneau Creek and the unnamed upland drainage are described in the following sections.

2.1.1 Soils and Subsurface Conditions

Previous investigations have shown that the hillside soils immediately below the spill point and the soils within the upland drainage, including the stock pond, have been impacted by sodium, chloride, and ammonia from the spill. The Phase II investigation collected additional samples to evaluate the depth of the impacted soil beneath the hillside and upland drainage, and to characterize soil conditions in the "beaver pond". Soil samples were not collected from the "beaver pond" during the previous investigation because the pond was flooded and mostly frozen. In addition, additional background soil samples were collected to evaluate the natural concentrations of metals and anions in soils of the area.

In addition to the sampling activities, drilling and trenching were utilized to provide a better understanding of the subsurface conditions at the site that affect the flow of water along the upland drainage. These conditions include the depth to and composition of permeable layers, the presence or absence of subsurface alluvium adjacent to the drainage channel observed at the surface, and the groundwater flow conditions within the upland drainage.

2.1.1.1 Background Soils

Soil samples were collected at two depths (0-1 ft and 2-4 feet) from three soil borings drilled in background areas. Figure 1 shows the locations of the background soil borings. The three borings were drilled on three different landforms in order to be representative of the range of background concentrations present in natural soils of the area. Background soil boring BK-2 was drilled on a bench to the north of the stock pond, boring BK-3 was drilled within a portion of the upland drainage upgradient of the spill entry point, and boring BK-4 was drilled on the top of a small hill at the same location as the background soil sample collected during February 2006. Boring logs for the soil borings are provided in Appendix A.

The background soil samples were analyzed for TAL metals (aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, selenium, silver, sodium, thallium, vanadium, and zinc), chloride, pH, SC, SAR, ESP, and CEC.

Table 1 provides the analytical results for the background soil samples, and Table 2 provides summary statistics for the six samples. The complete laboratory reports are provided in Appendix B.

Table 1 Background Soil Analytical Results

Parameter	Units	Sample ID					
		BKS2-1	BKS2-4	BKS3-S-1	BK3-S-4	BK4-S-1	BK4-S-4
	Depth (ft)	0-1	2-4	0-1	2-4	0-1	2-4
Metals							
Aluminum	mg/kg	4100	3800	4500	4900	7200	4800
Antimony	mg/kg	ND	ND	ND	ND	ND	ND
Arsenic	mg/kg	6.3	8.4	7.3	7.8	9.0	8.8
Barium	mg/kg	110	97	100	100	150	140
Beryllium	mg/kg	0.19	0.22	0.22	0.23	0.27	0.18
Cadmium	mg/kg	ND	ND	ND	ND	ND	ND
Calcium	mg/kg	2800	35000	1500	3300	4100	5300
Chromium	mg/kg	6.7	6.9	6.6	7.1	9.3	6.8
Cobalt	mg/kg	4.8	5.7	6.2	5.3	5.8	4.5
Copper	mg/kg	9.4	15	9.8	9.9	15	9.6
Iron	mg/kg	7900	9700	9200	11000	15000	19000
Lead	mg/kg	5.7	7.0	6.5	7.0	8.6	6.7
Magnesium	mg/kg	2000	11000	3100	3200	4000	3000
Manganese	mg/kg	360	310	470	410	370	320
Mercury	mg/kg	0.021	0.024	ND	0.021	ND	ND
Nickel	mg/kg	9.6	14	12	12	15	9.9
Potassium	mg/kg	1000	760	1100	700	1100	980
Selenium	mg/kg	ND	8.8	ND	ND	ND	ND
Silver	mg/kg	1.7	1.8	1.7	1.7	3.2	1.8
Sodium	mg/kg	46	920	670	1100	ND	160
Thallium	mg/kg	ND	ND	ND	ND	ND	ND
Vanadium	mg/kg	13	14	15	17	18	14
Zinc	mg/kg	27	34	30	29	38	39
Anions							
Chloride	mg/kg	84.7	69.5	15.3	12.1	4.6	9.2
Other Parameters							
pH	St units	7.36 J	8.37 J	7.85 J	7.77 J	8.64 J	9.18 J
Sp. Cond.	umhos/cm	123	209	986	1090	46.4	175
SAR	Ratio	0.525	7.05	8.65	15.0	0.255	1.36
ESP	%	0.494	7.11	8.89	11.3	0.470	1.74
CEC	meq per 100 g	18.9	16.1	24.1	19.7	23.8	18.0

ND = Not Detected

J = Estimated Value

Table 2 Summary Statistics for Background Soil Samples

Parameter	Units	Generic Soil Screening Level ¹	Range	Mean	Standard Deviation
Metals					
Aluminum	mg/kg		3800 – 7200	4883	1209
Antimony	mg/kg	31	<1.1 - <1.2		
Arsenic	mg/kg	0.4 ²	6.3 - 8.8	7.9	1.0
Barium	mg/kg	5500	97 – 150	116	23
Beryllium	mg/kg	0.1 ²	0.18 - 0.22	0.22	0.03
Cadmium	mg/kg	78	<0.76 - <0.8		
Calcium	mg/kg		1500 – 35000	8667	12963
Chromium	mg/kg	390	6.6 - 9.3	7.2	1.0
Cobalt	mg/kg		4.5 - 6.2	5.4	0.6
Copper	mg/kg		9.4 – 15	11.5	2.8
Iron	mg/kg		7900 – 19000	11967	4217
Lead	mg/kg	400	5.7 - 8.6	6.9	1.0
Magnesium	mg/kg		2000 – 11000	4383	3304
Manganese	mg/kg		310 – 470	373	60
Mercury	mg/kg		<0.019 - 0.024	0.022	0.002
Nickel	mg/kg	1600	9.6 – 15	12.1	2.2
Potassium	mg/kg		760 – 1100	940	171
Selenium	mg/kg	390	<7.6 - 8.8	8.8	
Silver	mg/kg	390	1.7 - 3.2	2.0	0.6
Sodium	mg/kg		<31 – 1100	579	463
Thallium	mg/kg		<7.6 - <7.9		
Vanadium	mg/kg	550	13 – 18	15	2
Zinc	mg/kg	23000	27 – 39	33	5
Anions					
Chloride	mg/kg		4.6 - 84.7	32.6	35.0
Other Parameters					
pH	St units		7.36 - 9.18	8.2	0.7
Sp. Cond.	umhos/cm		46.4 – 1090	438	469
SAR	Ratio		0.255 – 15.0	5.47	5.86
ESP	%		0.470 – 11.3	5.00	4.71
CEC	meq per 100 g		16.1 – 24.1	20.1	3.2

¹EPA Generic Soil Screening Levels²Carcinogenic risk level

Bolded values exceed the Soil Screening Level

All TAL metals analyzed were detected in the background soils, except for antimony, cadmium, and thallium. Two metals, arsenic and beryllium, are present in concentrations that exceed the EPA generic soil screening levels. These results are typical for soils that are derived from shales. The average concentration of arsenic in soils of the Western U.S. has been reported to range from 5.2 to 7.5 mg/kg, with a range of <0.1 to 97 mg/kg (Shacklette and Boerngen 1984 and references cited within). The concentration of arsenic in shales is generally elevated above these averages. Rose (2003) reported that the average concentration of arsenic in common shales and black shales is 12 mg/kg and 29 mg/kg, respectively. Beryllium in soils of the Western U.S. has been reported to range from <1 to 15 mg/kg (Shacklette and Boerngen 1984).

Background soil sodium concentrations range from less than 31 to 1,100 mg/kg, with a mean of 579 mg/kg. Chloride ranges from 4.6 to 84.7 mg/kg with a mean of 32.6 mg/kg. Sodium-adsorption ratio (SAR) ranges from 0.255 to 15.0.

2.1.1.2 Hillside, Upland Drainage, and Beaver Pond Soils

A total of seven borings were drilled and three trenches excavated into soils on the hillside, in and adjacent to the upland drainage, on the stock pond dam, and in and adjacent to the "beaver pond". The boring logs are included in Appendix A. Figure 1 shows the locations of the soil borings and trenches.

Table 3 provides the analytical results for the hillside and upland drainage soil samples collected. The complete laboratory reports are provided in Appendix B.

Table 3 Hillside and Upland Drainage Soil Analytical Results

		Sample ID					
		UD1-S-1	UD1-S-3	UD1-S-5	HS1-S-1	HS1-S-3	HS1-S-5
	Depth (ft)	0-1	1-3	3-5	0-1	1-3	3-5
Parameter	Units						
Chloride	mg/kg	3630	9160	16900	57.0	4760	8210
pH	St units	9.14 J	8.33 J	8.11 J	8.92 J	8.14 J	8.24 J
Sp. Cond.	umhos/cm	107	6730	18700	207	9670	7920
SAR	Ratio	32.6	68.4	93.9	27.6	79.0	97.0
ESP	%	18.6	13.7	7.36	30.4	37.6	52.1
CEC	meq per 100 g	29.6	16.7	14.1	15.4	5.09	7.89

J = Estimated value

Hillside Soils

One boring (HS-1) was drilled on the hillside below the spill site within the path of the spill, about halfway down the hill to the upland drainage. This boring was drilled to collect samples to characterize the nature of salt contamination beneath the hillside. Clayey silt was present from ground surface to one foot, gravelly sand fill material from one to five feet, and a relatively impermeable glacial outwash clay below this depth in this boring. According to the drillers, this clay material, which they called a glacial till, underlies many of the valleys in this area to substantial depths.

Three samples were collected from boring HS-1 at depths of 0-1 foot, 1-3 feet, and 3-5 feet bgs. These samples were analyzed for chloride, pH, SC, SAR, ESP, and CEC. Chloride ranged from 57 mg/kg to 8,210 mg/kg in these samples, and increased with depth. The samples from the two lower depth ranges are both over 100 times the mean background concentration for chloride, indicating that the soils between one and five feet depth have retained salt content from the spill. SAR ranged from 27.6 to 97.0 for the three samples.

Upland Drainage Soils and Subsurface Conditions

One boring (UD-1) was drilled within the upland drainage bottom at a location upgradient from the stock pond to evaluate the depth to impermeable layers and collect samples for soil characterization. Silty, sandy, gravelly clay was encountered in this boring to a depth of about 3 feet. A more permeable layer of sand was present between 3 and 7 feet bgs. This layer of sand is saturated with water with a very high conductivity, and is semi-confined. The water level in the boring rose from an initial level of about 5 feet to about 2 feet after a couple minutes. The basement glacial outwash clay was encountered at a depth of 7 feet in this boring.

Three samples were collected from boring UD-1 at depths of 0-1 foot, 1-3 feet, and 3-5 feet bgs. These samples were analyzed for chloride, pH, SC, SAR, ESP, and CEC. Table 3 provides the analytical results for the upland drainage soil samples. The complete laboratory reports are provided in Appendix B.

Chloride ranges from 3,630 mg/kg to 16,900 mg/kg in these samples, and increases with depth. SAR ranges from 32.6 to 93.9 for the three samples. Specific conductance increased from 107 umhos/cm at the surface to 18,700 umhos/cm in the sample from 3-5 feet depth.

One additional boring (UD-2) was drilled adjacent to the upland drainage downgradient from the hillside to evaluate the possible presence of a subsurface permeable layer that might act to transmit groundwater. This boring encountered glacial outwash clay at about 4 feet depth beneath surface silt layers, with no evidence of a permeable layer at this location. In addition, one trench was excavated in the upland drainage near the location of boring UD-1 to evaluate the channel morphology. The glacial outwash basement was encountered at about 7 feet depth in this trench. The outwash clay was also seen on the sidewalls of the trench at depths of about 2 feet. Therefore, it appears that permeable subsurface materials associated with the upland drainage are largely confined to the area directly beneath the visible surface channel.

One boring (SD-1) was drilled on the stock dam to evaluate the potential reasons why the stock pond has refilled with relatively good quality water at the same time that salt-impacted water continues to be released to Charbonneau Creek from the upland drainage. This boring encountered dam fill material to a depth of about 5.5 feet, sandy clay from 5.5 feet to 9 feet, and gravelly sand from 9 feet to 14.5 feet, where the outwash clay basement was encountered. Conductivity measurements showed that the water in the boring from the gravelly sand interval was very high in salt content. This boring was completed as a monitoring well to allow for the collection of a representative groundwater samples from this permeable interval.

Boring BP-3 was drilled adjacent to the upland drainage about halfway between the stock pond and the "beaver pond". This boring encountered clayey sand to a depth of 7.5 feet, with one 3-inch layer of gravel present at about 5.5 feet. Outwash clay was present below 7.5 feet to the total drilled depth of 22 feet. A monitoring well was installed in this boring to monitor the upper permeable layer.

"Beaver Pond" Soils and Subsurface Conditions

Three borings were drilled adjacent to the "beaver pond" to evaluate the subsurface conditions, including the depth to the outwash clay and the depths of permeable layers. Boring BP-1 was drilled near the Charbonneau Creek end of the pond. This boring encountered clayey sand to a depth of 6.5 feet and the basement outwash clay from 6.5 feet to the total depth of 22 feet. Two thin sandy layers were present within the outwash clay at depths of about 12 feet and 19 feet. An intermediate conductivity measurement of 9,880 umhos/cm was recorded in this boring. It is thought that the reading reflects the mixing of two water sources within the boring: slat-contaminated water from near the surface, and fresh water entering from the deeper sandy layers.

Boring BP-2 was drilled adjacent to the upper end of the "beaver pond" and encountered clayey sand from 0 to 8 feet and the basement outwash clay from 8 feet to the total depth of 12 feet. The upper layer of alluvium became coarser-grained and gravelly with depth. Conductivity measurements in this boring showed the water to be fresh at this location.

Two trenches were excavated into the "beaver pond" at the locations shown on Figure 1 using a trackhoe. These trenches were excavated to determine the depth to bedrock or clay layers beneath the "beaver pond" and to collect samples to characterize the impacts to the soils within the pond. Trench BP-S1 encountered silty sand from 0-1 feet and a fine-coarse grained gravelly sand at about 5 feet. The basement glacial clay was encountered at a depth of 8-9 feet in this trench. Trench BP-S2 also encountered a coarse-grained layer at about 5 feet depth, but was not excavated deeper.

Samples were collected directly from the bucket of the trackhoe at two depths (0-1 foot and 4-5 feet) from each trench. These samples were analyzed for chloride, pH, SC, SAR, ESP, and CEC. The results are contained in Table 4. The complete laboratory reports are provided in Appendix B.

Table 4 Beaver Pond Soil Analytical Results

		Sample ID			
		BP-S1-1	BP-S1-5	BP-S2-1	BP-S2-5
	Depth (ft)	0-1	4-5	0-1	4-5
Parameter	Units				
Chloride	mg/kg	5150	69.6	5860	1550
pH	St units	8.55 J	8.33 J	7.88 J	7.85 J
Sp. Cond.	umhos/cm	7560	1050	7030	2650
SAR	Ratio	63.4	13.7	18.2	8.33
ESP	%	33.4	16.5	49.5	18.6
CEC	meq per 100 g	10.1	8.15	23.2	5.77

J = Estimated value

Chloride was present in the surface samples from the "beaver pond" at concentrations of 5,150 mg/kg and 5,860 mg/kg. Chloride was reported in the 4-5 foot sample from trench BP-S1 at 69.6 mg/kg, and in the 4-5 foot sample from trench BP-S2 at 1,550 mg/kg. SAR ranged from 13.7 to 63.4 in the "beaver pond" soils.

2.1.2 Surface Water and Groundwater

Water samples were collected from the stock pond, Charbonneau Creek immediately downstream from the insertion point, the two new monitoring wells, and one background surface water location during the Phase II investigation. The locations of the water samples are shown on Figure 1. The analytical results for these samples are contained in Table 5, and the complete laboratory reports are provided in Appendix B.

Table 5 Surface Water and Groundwater Analytical Results

		Sample ID				
		BKW-1	SPW-1	CCW-1	SD-1-W-1	BP3-W-1
	Source	Char. Creek Back-ground	Stock Pond	Char. Creek Insertion	Stock Dam GW	Beaver Pond GW
Parameter	Units					
Metals						
Aluminum	mg/L	ND	0.11 J	0.12 J	13 J	5.6 J
Antimony	mg/L	ND	ND	0.026	ND	ND
Arsenic	mg/L	ND	ND	ND	ND	ND
Barium	mg/L	0.042	0.12	0.044	1.7	0.14
Beryllium	mg/L	ND	ND	ND	ND	0.0027
Cadmium	mg/L	ND	ND	ND	ND	ND
Calcium	mg/L	47	150	61	8300	3000
Chromium	mg/L	ND	ND	ND	ND	ND
Cobalt	mg/L	ND	0.0054	ND	0.12	ND
Copper	mg/L	ND	ND	0.0054	ND	0.0055
Iron	mg/L	0.28	0.55	0.68	1.9	ND
Lead	mg/L	ND	ND	ND	ND	ND
Magnesium	mg/L	57	180	62	1300	1500
Manganese	mg/L	0.060	0.21	0.36	36	0.81
Mercury	mg/L	ND	ND	ND	ND	ND
Nickel	mg/L	0.013	0.013	0.015	0.24	0.058
Potassium	mg/L	14	25	15	1700	29
Selenium	mg/L	ND	ND	ND	ND	ND
Silver	mg/L	ND	ND	ND	ND	ND
Sodium	mg/L	410	680	550	46000	4500
Thallium	mg/L	ND	ND	ND	ND	ND
Vanadium	mg/L	ND	ND	ND	ND	ND
Zinc	mg/L	ND	ND	ND	ND	ND
Anions						
Chloride	mg/L	8.72	395	267	19500	111000
Sulfate	mg/L	1110	2110	1170	1780	954
Ammonia	mg/L	ND	ND	ND	ND	408
Field Parameters						
pH	St units	8.98	7.87	8.19	6.36	6.90
Sp. Cond.	umhos/cm	2590	4780	2740	179300	51600
Temperature	Deg. C	19.2	19.4	19.0	11.7	8.0

ND = Not Detected

J = Estimated value

Metals detected in the background water sample BKW-1, collected upgradient of the Monson Ranch on Charbonneau Creek, were barium, calcium, iron, magnesium, manganese, nickel, potassium, and sodium. Sodium was reported at 410 mg/L and chloride was present at 8.72 mg/L in this sample. Ammonia was not detected in this sample. The specific conductance was 2,590 umhos/cm and the water is alkaline, with a pH of 8.98 units.

Water in the stock pond (sample SPW-1) contains more calcium, magnesium, and potassium, in addition to slightly elevated sodium (680 mg/L) and chloride (395 mg/L), as compared to the background sample. Aluminum and cobalt are also present in the stock pond water.

The sample from Charbonneau Creek (CCW-1), which was collected just downstream from the spill insertion point, contains similar levels of the major cations (calcium, magnesium, sodium, and potassium) as the background sample. Barium, iron, manganese, and nickel were detected in this sample and in the background sample. Aluminum, antimony, and copper were also detected in this sample, but were reported as non-detect in the background sample.

One groundwater sample was collected from each of the two monitoring wells installed. Sample SD-1-W-1 was collected from the stock dam well. This well was screened in the permeable subsurface layer encountered in the boring from 9-14.5 feet bgs. The sample results show that this water contains slightly to highly elevated concentrations of aluminum, barium, calcium, cobalt, iron, magnesium, manganese, nickel, potassium, sodium, and chloride when compared to the background sample. The pH is acidic at 6.36 units, and the specific conductance was very high at 179,300 umhos/cm.

The groundwater sample collected from well BP-3, located adjacent to the upland drainage channel between the stock pond and the "beaver pond", showed values of aluminum, barium, calcium, manganese, nickel, potassium, sodium, and chloride that are intermediate between the background sample and the stock pond dam groundwater sample. This sample contained higher magnesium than the groundwater sample from well SD-1, and also reported ammonia at a concentration of 408 mg/L. The pH was 6.90 and the specific conductance was 51,600 umhos/cm.

2.1.3 Charbonneau Creek Sediments

Sediments in Charbonneau Creek were previously determined to have been impacted by sodium and chloride from the spill. Six sediment samples were collected during this investigation from pool areas along Charbonneau Creek using an Eckmann Dredge to assess the persistence of the chloride impacts and evaluate metals concentrations in the sediments. The locations of these samples are shown on Figure 2.

All six samples were analyzed for chloride. The chloride results are provided in Table 6 and the complete laboratory reports are contained in Appendix B.

Table 6 Sediment Chloride Results

Sample ID	Chloride (mg/kg)
CCSED-1	2810
CCSED-2	4380
CCSED-3	1240
CCSED-4	1850
CCSED-5	242
CCSED-6	39.9

Chloride concentrations ranged from 39.9 mg/kg to 4,380 mg/kg in these samples, and generally decreased in a downstream direction. The chloride concentration was within the range of concentrations for the background soils samples at sampling point CCSED-6.

Sample CCSED-1, collected from the first pool downgradient of the spill insertion point, was analyzed for metals and ammonia in addition to chloride. The analytical results are provided in Table 7 and the complete laboratory reports are contained in Appendix B.

Table 7 Sample CCSED-1 Analytical Results

Parameter	Units	CCSED-1
Metals		
Aluminum	mg/kg	1600
Antimony	mg/kg	ND
Arsenic	mg/kg	3.3
Barium	mg/kg	51
Beryllium	mg/kg	0.075
Cadmium	mg/kg	ND
Calcium	mg/kg	8700
Chromium	mg/kg	2.2
Cobalt	mg/kg	2.2
Copper	mg/kg	5.5
Iron	mg/kg	4500
Lead	mg/kg	ND
Magnesium	mg/kg	2300
Manganese	mg/kg	130
Mercury	mg/kg	ND
Nickel	mg/kg	4.9 U
Potassium	mg/kg	460
Selenium	mg/kg	ND
Silver	mg/kg	0.84
Sodium	mg/kg	2000
Thallium	mg/kg	ND
Vanadium	mg/kg	6.0
Zinc	mg/kg	14
Anions		
Chloride	mg/kg	2810
Ammonia	mg/kg	91.1

ND = Not Detected

U = Not detected at an estimated detection limit

All TAL metals except antimony, cadmium, lead, mercury, selenium, and thallium were detected in sediment sample CCSED-1. All metals results except for sodium are lower than the mean concentration for that metal for the six background soil samples. Sodium was detected at 2,000 mg/kg, about 3.3 times the background soils concentration of 579 mg/kg. These results are consistent with the previous sampling results that showed only chromium and sodium higher than background for the sediments. In addition to the metals, ammonia was detected at a concentration of 91.1 mg/kg in this sample. Ammonia was not previously detected in any sediment samples. Chloride in this sediment sample was detected at a concentration of 2,810 mg/kg, about 86 times the mean background concentration in the soils.

2.1.4 Summary of Impacts

2.1.4.1 Hillside Soils

The hillside soils have been impacted by chloride and sodium (and likely, ammonia) from the spill. Chloride ranged from 57 mg/kg to 8,210 mg/kg in the three samples collected, and increased with depth. The samples from the two lower depth intervals are both over 100 times the mean background concentration for chloride. The surface sample has likely been leached of salts, accounting for the low chloride concentration at the surface. SAR ranged from 27.6 to 97.0 for the three samples. These values are above the mean background value of 5.47 and are above the range (up to 9) where revegetation can occur.

2.1.4.2 Upland Drainage Soils

Samples collected within the upland drainage indicate that the drainage soils have been impacted by chloride and sodium (and likely, ammonia). Chloride ranged from 3,630 mg/kg to 16,900 mg/kg in these samples, and increased with depth. SAR ranged from 32.6 to 93.9 for the three samples, as compared to the mean background value of 5.47.

2.1.4.3 "Beaver Pond" Soils

Samples collected within the "beaver pond" indicate that the soils and sediments within the pond have been impacted by chloride and sodium (and likely, ammonia). Chloride was present in the surface samples from the "beaver pond" at concentrations of 5,150 mg/kg and 5,860 mg/kg. Chloride was reported in the 4-5 foot sample from trench BP-S1 at 69.6 mg/kg, and in the 4-5 foot sample from trench BP-S2 at 1,550 mg/kg. SAR ranged from 13.7 - 63.4 for the four samples, as compared to the mean background value of 5.47.

2.1.4.4 Charbonneau Creek Sediments

Sediments in Charbonneau Creek near the spill insertion point remain impacted by chloride from the spill. Chloride concentrations ranged from 39.9 mg/kg to 4,380 mg/kg in the six sediment samples, and generally decreased in a downstream direction. The chloride concentration was within the range of concentrations for the background soils at sampling point CCSED-6.

Sample CCSED-1, collected from the first pool downgradient of the spill insertion point,

was analyzed for metals and ammonia in addition to chloride. Sodium was detected at 2,000 mg/kg, about 3.3 times the background soils concentration of 579 mg/kg. All other metals detected were lower than or equal to (for calcium) the mean of the background soil samples for that metal. In addition to sodium and chloride, ammonia was detected at a concentration of 91.1 mg/kg in this sample. Ammonia was not previously detected in any sediment samples, but has been shown to be related to the spill event.

2.1.4.5 Surface Water

Charbonneau Creek

Water sampling results show that water within Charbonneau Creek continues to be impacted by chloride from the spill. In addition, aluminum, antimony, copper, iron, and manganese are elevated as compared to the background sample. Iron and manganese are present at concentrations about 3 and 6 times the background values for these metals, respectively. Aluminum, antimony, and copper were also detected at trace concentrations in the sample from Charbonneau Creek, but were reported as non-detect in the background sample.

Stock Pond

Water sampling results show that the stock pond currently contains water that has metals concentrations intermediate between those of the background sample (and Charbonneau Creek) and groundwater samples collected from the permeable layer below the stock pond dam. Water in the stock pond (sample SPW-1) contains more calcium, magnesium, and potassium, in addition to slightly elevated sodium (680 mg/L) and chloride (395 mg/L), as compared to the background sample. Aluminum and cobalt are also present in the stock pond water. These results suggest that the water in the stock pond is a mixture of fresh water and impacted water that seeps into the pond from below.

2.1.4.6 Groundwater

Groundwater sampling results show that highly impacted groundwater exists below the stock pond dam and upland drainage between the stock pond and the "beaver pond". Sample results from the stock pond dam well show that this water contains slightly to highly elevated concentrations of aluminum, barium, calcium, cobalt, iron, magnesium, manganese, nickel, potassium, sodium, and chloride when compared to the background sample. The pH is acidic at 6.36 units, and the specific conductance was very high at 179,300 umhos/cm.

The groundwater sample collected from well BP-3, located adjacent to the upland drainage channel between the stock pond and the "beaver pond", shows values of aluminum, barium, calcium, manganese, nickel, potassium, sodium, and chloride that are intermediate between the background sample and the stock dam groundwater sample. This sample contained higher magnesium than the stock pond groundwater sample, and also reported ammonia at a concentration of 408 mg/L. The pH was 6.90 and the specific conductance was 51,600 umhos/cm.

3.0 REMEDIATION AND MONITORING PLAN

This section presents the revised remediation plan for continued cleanup and restoration of the site and continued monitoring of conditions in Charbonneau Creek.

3.1 CONCEPTUAL SITE MODEL

The Phase II Site Investigation provided considerable data necessary to interpret the subsurface conditions at the site and the flow of groundwater in the alluvium of the upland drainage. Based on the results of the drilling and trenching program, and the analytical results for the samples collected, the conceptual site model can be described as follows:

- The hillside soils consist of sandy and gravelly material that was excavated in association with the gravel pits to the west of the spill site to a depth of about 5 feet. This material was graded over the original surface in this location.
- The upland drainage is underlain by relatively impermeable glacial outwash clay at depths ranging from about 4 feet near the spill site to about 8-9 feet at the "beaver pond".
- A semi-confined layer of alluvium is present in the bottom of the upland drainage channel from near the spill site to below the stock pond. This layer consists of sand and gravel and is present upstream of the stock pond at depths of 3-7 feet, and beneath the stock pond at a depth of about one foot below the pond bottom. This layer contains groundwater that has been heavily impacted by the spill. This layer extends beneath the stock pond and emerges below the stock pond dam into the upland drainage and "beaver pond".
- Below the stock pond, the permeable layer observed in the subsurface upstream along the upland drainage is present from the surface to a depth of about 7-8 feet, and rests directly on top of the outwash clays.
- The subsurface geometry of the upland drainage largely mimics the channel observed at the surface. In the lower portions of the upland drainage, there is some alluvium present outside of the surface channel but groundwater within this alluvium has not been impacted by the spill in most areas.
- Groundwater that has been impacted by the spill moves slowly in the subsurface permeable layer along the upland drainage and beneath the stock pond. This impacted groundwater emerges at several locations downstream of the stock pond, including the area just downstream of the stock pond dam and the upper reaches of the "beaver pond".
- Impacted water from the "beaver pond" flows into Charbonneau Creek via a shallow subsurface pathway that leads from the "beaver pond" to the creek.
- Water within the stock pond is not stratified. The intermediate water quality currently present in the stock pond is the result of a mixture of fresh water that filled the pond during the spring runoff and impacted water.

3.2 PREVIOUS AND CURRENT REMEDIATION EFFORTS

Cleanup activities were initiated by Zenergy immediately upon discovery of the spill. The pipeline was repaired on January 4, 2006 within 6 hours of the discovery, and the North Dakota Industrial Commission and available area landowners notified of the incident. Removal of water from the unnamed drainage was initiated the same day. Hot-water washing was employed along the upper reaches of the upland drainage to remove petroleum constituents that were present coating vegetation within the channel of the upland drainage.

Pumping of the water from the two ponds located further downstream along the unnamed drainage was initiated later that day. The stock pond and "beaver pond" were pumped over the next few days until they were essentially dry. Currently, as additional water infiltrates these impoundments they are periodically emptied.

Pumping of affected water from Charbonneau Creek was also begun from two areas of the creek immediately downstream from the insertion point within a few days of the spill. Two small temporary earthen dams were constructed at these locations to impound the affected water. Pumping was also initiated at the north boundary of Section 33 T150N, R102W where a third temporary dam was constructed at the culvert crossing to restrict the migration of the spill. The recovered water is transported by vacuum truck, and more recently, by a temporary pipeline, to the Zenergy Wolf #1 Salt Water Disposal Well for disposal.

Following excavation of the trench at the UD-1 boring site during the Phase II investigation, a slotted PVC culvert was placed in the trench and a submersible pump installed in the culvert. Impacted groundwater has been pumped from the subsurface permeable layer at this location at the rate of about 100 barrels per day since late May 2006.

3.3 PROPOSED FUTURE REMEDIATION

In consultation with Zenergy, the North Dakota Department of Health, the North Dakota Industrial Division, and affected landowners, additional remediation and monitoring will be conducted at the site. There are two main goals of the remediation process: 1) to stop the flow of salt-contaminated water into Charbonneau Creek from the upland drainage, and 2) to restore vegetation in the upland drainage and adjacent areas to conditions existing before the spill. Stopping the flow of salt-impacted water into Charbonneau Creek is the highest priority for the remediation.

The additional remediation has five components: 1) the construction of a slurry cut-off wall at a narrow point along the upland drainage near monitoring well BP-3, upstream from the "beaver pond", 2) the installation and operation of additional groundwater extraction wells upgradient of the slurry cut-off wall, 3) removal of impacted soils from the "beaver pond", 4) treatment of soils within the upland drainage and on the hillside using chemical amendments, and 5) site restoration. Figure 3 shows the conceptual plan for the remediation and provides the surface areas for four portions of the upland drainage: the "beaver pond", the lower drainage, the stock pond, and the upper drainage. Each of the remediation components and the proposed long-term monitoring is described below.

3.3.1 Construction of a Slurry Cut-Off Wall

In accordance with the immediate goal of stopping the flow of salt-impacted water into Charbonneau Creek, a slurry cut-off wall will be constructed across the upland drainage near monitoring well BP-3. This location has been chosen because the upland drainage is confined to a narrow channel at this point. The slurry cut-off wall will be excavated using a trackhoe and the trench kept open using a bentonite slurry during excavation. The excavation will extend into the basement outwash clay on the sides and bottom of the trench for about 2 feet. Following excavation, cement will be added to the trench to solidify the mixture of bentonite and cement into a solid, impermeable wall.

The installation of the slurry cut-off wall will capture all subsurface flow in the drainage. This subsurface flow has been demonstrated to be the main source of the salt-impacted water that is emerging into the base of the "beaver pond" via a series of springs. The wall will be designed to pass flood flows over the top of the wall during the spring runoff or large precipitation events. The construction of the slurry cut-off wall will not materially affect the surface characteristics or use of the land.

3.3.2 Installation and Operation of Extraction Wells

Three additional extraction wells will be installed within the upland drainage upstream from the slurry cut-off wall, in addition to the extraction well installed during the Phase II investigation in the trench near boring UD-1. One well will be located near monitoring well BP-3, the second well will be located just downstream of the stock pond dam, and third well on the upstream side of the stock pond. The wells will be drilled using a hollow-stem auger drill rig or installed in trenches dug by a trackhoe. A submersible pump will be installed in each well. The pump intakes will be located within the permeable subsurface layer identified during the Phase II investigation. Impacted water pumped from this layer will be transported by temporary pipeline to the Zenergy Wolf #1 Salt Water Disposal Well for deep injection.

Currently, about 100 barrels per day of salt-impacted water is being recovered from the extraction well near boring UD-1. The proposed system would increase the extraction rate to about 400 barrels per day. Using GPS tracking obtained during the Phase II investigation, the total area of the upland drainage upstream from the slurry cut-off wall is approximately 210,000 square feet. Assuming a saturated interval of about 4 feet, as seen in boring UD-1, a total of about 150,000 barrels of water is contained within the subsurface permeable layer. Therefore, it is estimated that the extraction system will need to operate for about one year to exchange one volume of impacted water within the subsurface permeable layer.

3.3.3 Removal of Impacted Soils

In order to remove the source of salt impacts to Charbonneau Creek from downstream of the interception system, impacted soils will be excavated and removed from the "beaver pond". Removal of impacted soils from this area will reduce the chance that additional slugs of impacted water would be released to Charbonneau Creek via the subsurface drainage pathway identified in the Phase II investigation, as well as restore the pond to useful conditions. The excavation and restoration of the "beaver pond" area is contingent upon consultation with and approval of the affected landowner and the

Army Corps of Engineers. If necessary, a Section 404 Dredge and Fill Permit will be obtained.

The soils will be excavated using a trackhoe or dredge and loaded on trucks for removal from the site. Soils removed from the site would be transported to a commercial landfill for disposal. Excavation of all soils above the basement outwash clay would be performed in the portion of the "beaver pond" that currently does not support vegetation. The pond will be left open to provide a new source of water for the landowner. The sides of the pond will be graded to eliminate any steep slopes into the pond area to allow for use by livestock and wildlife.

The area of the "beaver pond" that would require excavation was estimated to be about 36,000 square feet during the Phase II investigation using GPS tracking. Assuming an average depth of 8 feet of excavation, approximately 10,700 cubic yards (6.6 acre-feet) of soils will be removed from the "beaver pond".

Soils would not be excavated from the channel of the upland drainage upgradient of the stock pond or the stock pond itself because the increased erosion that would likely result would cause accelerated siltation of the stock pond and possibly reduce the effectiveness of the groundwater interception system. With implementation of the groundwater extraction system, and treatment of the drainage soils, excavation of the stock pond soils is not considered necessary.

3.3.4 Treatment of Impacted Soils in the Upland Drainage and Hillside

Shallow soils within the upland drainage and on the hillside below the spill point will be treated to reduce the concentrations of sodium in the soils and encourage revegetation. The wetland area of the upland drainage between the excavated portion of the "beaver pond" and the slurry cut-off wall would also be treated. The estimated surface area requiring treatment is about 140,000 square feet.

Treatment will be accomplished by amending the soils with gypsum and sulfur. Gypsum (hydrated calcium carbonate) provides calcium ions that displace sodium ions from adsorption sites on clay minerals. The sodium is released from the soil and washes away over time, thus restoring SAR values to within acceptable limits. The addition of sulfur is also necessary because of the strongly alkaline soils. The sulfur will create sulfuric acid which will reduce the pH of the soils to an optimum range for the cation replacement reactions to occur. These amendments will be placed on the surface and then tilled into the soil to a depth of about two feet, in accordance with guidance provided in the document *Remediation of Salt-Affected Soils at Oil and Gas Production Facilities* (API 1997). Water percolating through the soils will carry the calcium ions to deeper depths in the soil column, thus it is not necessary to amend the soils to depths deeper than two feet.

The hillside and upland drainage will be protected during the remediation process by use of straw mulch and hay bail dams. All disturbed areas will be covered with straw mulch to reduce erosion. In addition, hay bales will be placed at regular intervals along the upland drainage to act as silt dams.

Biological Impact and Recovery Monitoring

Biological recovery monitoring will be conducted as needed to document the recovery of the aquatic ecosystem, as described in previous reports.

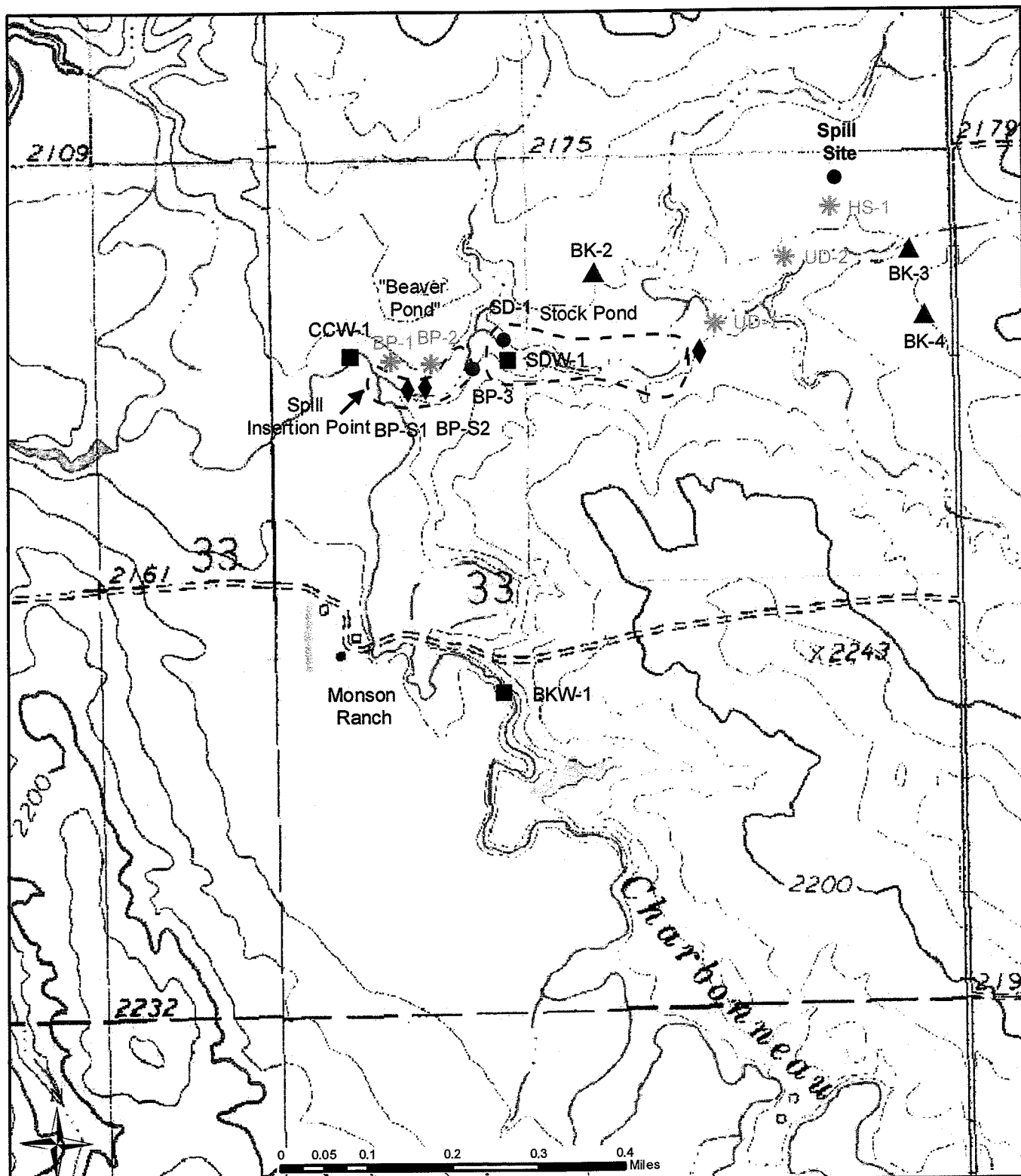
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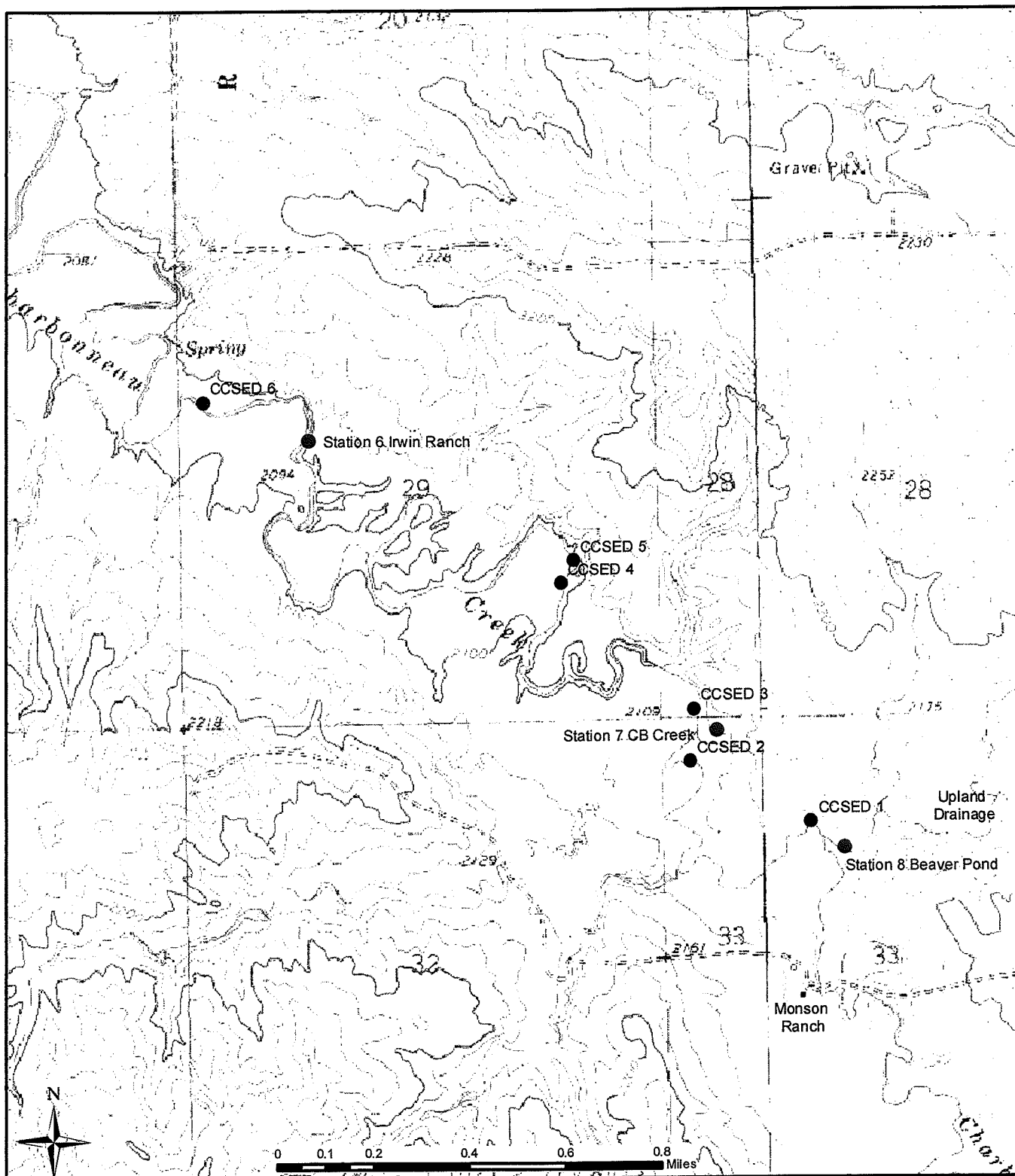
- Monitoring Well
- ▲ Background Soil Boring
- Background Stock Pond, and Charbonneau Creek Water Sampling Location
- * Hillside, Upland Drainage, and Beaver Pond Boring
- ◆ Trench

Soil and Water Sampling Locations May 22-25, 2006

Location: Williston Basin, North Dakota

Buys and Associates, Inc.
Environmental Consultants

Figure 1



- Water Quality Monitoring Stations
- Phase II Sediment Sampling Locations

Water Quality and Sediment Sampling Locations on Charbonneau Creek

Location: Williston Basin, North Dakota

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Figure 2

